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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

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Reliability of Structural Fire Protection

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Fire resistant compartmentation has long been the core of fire safety measures. If a building is provided with such compartments, any fire occurring in the building is expected to be confined to the compartment of origin and not to spread to other parts of the building. If the structural boundaries of a compartment,walls, floor and ceiling, are of sufficient fire resistance, it is argued, the compartment will not "fail" for a specified length of time defined as the fire resistant period. Compartment failure and violation of performance criteria relating to load bearing capacity, integrity or thermal insulation can occur if and when a fire grows to a fully developed (flash-over) stage and produces intense heat which can cause a progressive deterioration of the structural boundaries.

For assessing the likelihood of failure of a structural element, analytical (deterministic) models have been developed in fire science literature to provide an estimate of the maximum heat or fire severity expected to be attained in a real fire in the compartment. These models are based on scientific theories supported by experimental data and do not take sufficient account of the uncertainties caused by several factors. The spread of fire is a stochastic phenomenon [1] and the maximum severity likely to be produced can only be predicted in probabilistic terms. Several factors also cause uncertainties in the estimates of fire resistance of structural elements provided by standard fire tests. Fire resistance is also affected by weakness caused by penetrations, doors or other openings in the structural barriers of a compartment. Accepting that, both the fire severity, S, and resistance, R, are random variables, probabilistic models [2] have been developed in recent years for evaluating the probability of failure of a structural element.

Depending on data available for analysis, an appropriate probabilistic model may be applied to any type of compartment for determining the fire resistance required for a structural element for any acceptable level for the probability of failure. However, the fire resistance of an element as judged in standard fire tests, is usually known since it should satisfy a minimum level specified in fire safety regulations and codes. The problem, however, is to evaluate the reliability of the element in performing satisfactorily in a real fire for the resistance period, t, for which it has been designed. This performance depends on several factors affecting severity and resistance [3]. Reliability is defined as the probability of success and is a function, R(t), of the time t. Its counterpart unreliability is the probability of failure and is given by [1 - R(t)].

Estimates of reliability for individual structural elements such as walls, floor and ceiling can provide an estimate of the reliability of the compartment which may be regarded as a "system" in reliability terminology. A compartment would "fail" if any of the structural elements "fail". Hence, it would be appropriate to regard the structural elements as constituting a "series" system [4]. The reliability of the compartment in satisfying a specified fire resistant period is, therefore, the product of the reliabilities of the four walls, floor and ceiling. This fundamental theorem in reliability theory indicates that the reliability of a compartment can be lower than that of any structural element. For example, for a specified fire resistance period t, the reliability of the comportment is 0.78 if the reliability of each of the four walls is 0.95 and the reliability of the ceiling or floor is 0.98. A compartment is unlikely to have 60 minutes fire resistance if the structural elements have 60 minutes fire resistance.

The fundamental result mentioned above is only valid if the failure of a structural element in a fire does not affect the performance of any other structural element, i.e. the structural elements are independent in regard to their fire performance. This may not be true since progressive deterioration of a wall under severe heat might, in some buildings, affect the performance of the floor or ceiling of a compartment. Likewise, a fire-resisting wall may be affected by the deflection of a beam in a fire - see Fig.1. Joints and other constructional features are likely to cause such a dependency. There is a need to carry out an investigation to identify and quantify the interactions between structural elements such as columns and beams which may exercise critical effects on the probability of compartment success or failure in a fire.

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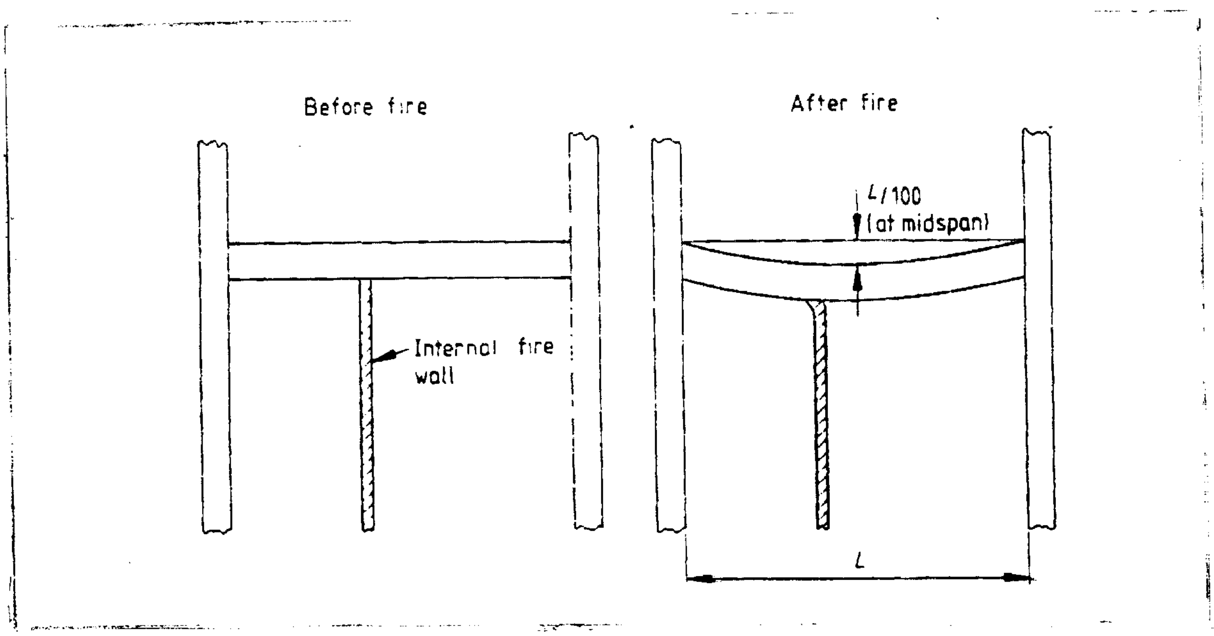

Figure 1 Effect of beam deflection on a fire-resisting wall.
Source: British Standard BS 5950: Part 8, 1990, Section four, page 15.